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13. ABSTRACT *(Maximum 200 words)*
The purpose of this study was to investigate if protective overgarments made from the same material but with different moisture vapor transmission rates would influence thermoregulatory responses in volunteers exposed to typical indoor workplace environments. Eight volunteers wore an impermeable overgarment (IO) and a permeable overgarment (PO) during a 4 h sedentary exposure at 18.3°C/50% rh (COOL) and 29.7°C/52% rh (WARM). During both COOL and WARM, skin and core temperatures were lower when wearing the PO. Skin wettedness was significantly higher during both COOL and WARM when wearing the IO. The IO had the highest weight increase due to absorption of non-evaporated moisture vapor during the 4 h test. These results showed that a moisture vapor permeable overgarment reduced overall thermal strain, minimized underclothing absorption of sweat and increased evaporation of moisture vapor during an extended sedentary exposure to simulated workplace environments.



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# EFFECTS OF WEARING IMPERMEABLE AND PERMEABLE PROTECTIVE CLOTHING ON THERMOREGULATORY RESPONSES WHILE SEDENTARY

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## INTRODUCTION

The use of protective clothing as a barrier against occupational and environmental hazards has increased dramatically in recent years. Certain types of protective overgarments are also being utilized in cleanroom manufacturing environments where contamination of the work site by personnel is a major concern. In the computer semiconductor manufacturing business, there is a reported industry-wide perception that the sedentary nature of the work does not justify the wearing of more costly, "breathable" protective clothing versus inexpensive, disposable, non-permeable garments. It is understandable that some managers of large-scale, industrial protective clothing and equipment programs would purchase specific garments based solely on a minimal cost per unit basis. Nevertheless, a recent study suggests that the use of higher-cost, vapor-permeable, and reusable protective clothing can actually be more economical when analyzed on a cost per use basis (1). The purpose of this present study was to investigate if protective overgarments manufactured from the same basic materials but with different levels of permeability would have an influence on thermoregulatory responses in volunteers who were sedentary and exposed to two typical indoor workplace environments.

## MATERIALS AND METHODS

Eight healthy males (age= 21.0 ±1.9 yrs, height=173.3 ±5.6 cm, weight=72.5 ±6.3 kg, body surface area=1.86 ±0.10 $m^2$) volunteered for the study. They were informed of the purpose, procedures and risks of the study. All volunteers expressed an understanding of the study by signing a statement of informed consent. All test overgarments were manufactured from material containing a waterproof/ breathable, protective membrane. The material was made by W.L. Gore and Associates. The protective membrane was composed of a thin layer of microporous polytetrafluoroethylene (PTFE). The PTFE membrane can be manufactured with varying levels of permeability. Test overgarment materials were evaluated by the manufacturer for permeability according to ASTM Standard E96-80 (2) which is used to calculate a moisture vapor transmission rate (MVTR, $g \cdot m^{-2} \cdot 24\ h^{-1}$). All volunteers wore both an impermeable overgarment (IO, MVTR=5) and a permeable overgarment (PO, MVTR=864) during a 4-hour sedentary exposure to two different environments: 18.3°C/50% rh (COOL); 29.7°C/52% rh (WARM). There was a constant air velocity of 1.1 $m \cdot s^{-1}$ directed at the volunteers as they sat in the climatic chamber. All volunteers also wore lightweight 100% polyester underwear, gloves, socks, and leather boots. Mean weighted skin temperature ($\bar{T}_{sk}$, 8 sites, °C), rectal temperature ($T_{re}$, °C), skin wettedness (w, %) calculated from dew point temperature within the overgarment, and heart rate (HR, bpm) were measured. Total body mass loss ($\dot{m}_b$, $g \cdot h^{-1}$) and moisture absorption (g) by the various garments were determined by pre- and post-experiment weights of all clothing items.

## RESULTS

Table 1. Initial and final values (Mean ± 1 SD) of $\bar{T}_{sk}$ and $T_{re}$ of volunteers (n=8) when wearing the IO and PO during COOL and WARM.

| GARMENT | | COOL | WARM |
|---|---|---|---|
| **IO** | Initial $\bar{T}_{sk}$ | 29.5 (1.0) | 30.8 (1.6) |
| | Final | 27.8 (0.9) | 32.9 (1.5) |
| | Initial $T_{re}$ | 36.9 (0.2) | 37.0 (0.3) |
| | Final | 36.5 (0.5) | 37.2 (0.2) |
| **PO** | Initial $\bar{T}_{sk}$ | 29.2 (1.3) | 30.7 (1.3) |
| | Final | 27.7 (0.7) | 32.1 (1.3) |
| | Initial $T_{re}$ | 36.9 (0.3) | 37.0 (0.3) |
| | Final | 36.3 (0.7) | 36.9 (0.3) |

Figure 1. shows w of the volunteers while wearing both overgarments during COOL and WARM. There were significant increases in w during both environmental conditions when wearing the IO. At 4 hours exposure, w approached 0.9 when wearing the IO during WARM. Excessive skin wettedness has been shown to exacerbate the rate of body heat storage (3, 4).

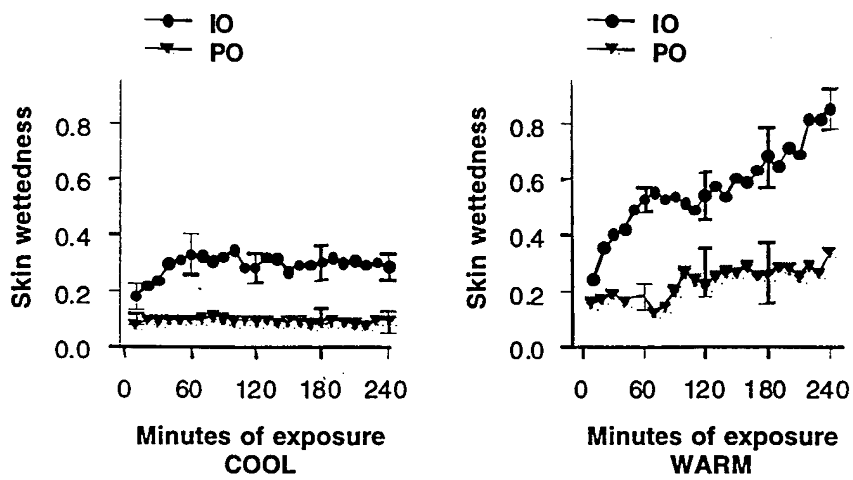


Figure 1. Local skin wettedness (Mean ± 1 SD) of volunteers (n=8) while wearing the IO and PO during COOL and WARM as a function of time of exposure.

Although there were no significant differences in HR when wearing either overgarment, HR during WARM was elevated an average of 24% and 19% above COOL values with the IO and PO, respectively. Mean $\dot{m}_b$ was lower during COOL (IO=77.5, PO=78.5) and higher during WARM (IO=92.3, PO=103) The IO had the highest mean weight increase (11 g, COOL and 44 g, WARM) due to absorption and/or condensation of non-evaporated moisture vapor within the overgarment during the 4-hour test. Absorption of moisture vapor also caused higher mean underclothing/footwear weight increases (22 g, COOL and 43 g, WARM) when worn with the IO. These weight increases were lower (20 g, COOL and 13 g, WARM) when wearing the PO.

## CONCLUSIONS

These results showed that a moisture-vapor-permeable overgarment reduced overall thermal strain, reduced underclothing absorption of sweat and increased evaporation of moisture vapor when compared with a non-permeable overgarment during an extended sedentary exposure to simulated workplace environments. Cleanroom personnel can be required to wear completely-encapsulating protective clothing ensembles for up to 12 hours during an extended work shift. The use of protective clothing ensembles with sufficient thermal resistance and increased levels of moisture vapor transmission can improve overall thermal comfort that could lead to subsequent improvements in task performance and workforce morale.

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